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Original research article

Breast telecobalt beam therapy using multi-isocentric technique

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ABSTRACT

Aim: To treat breast cancer patients in telecobalt unit with image based conformal radiotherapy planning using the multi-isocentric technique.

Background: Breast cancer is the leading cancer among all the female cancers. With improved screening techniques, many patients are being diagnosed at an early stage and the need for radiotherapy in such patients has increased. The telecobalt machine is still a preferred machine in many of the low income countries as it is cost-effective and can offer uninterrupted treatment to large number of patients.

Materials and Methods: Three hundred patients requiring radiotherapy had a computed tomography based planning. Patients were immobilized using a breast board with a thermoplastic mould. Three dimensional planning was done with the multi-isocentric technique. These patients were then simulated using a Nucletron Simulix digital simulator for field verification and were treated in a Theratron Phoenix telecobalt treatment unit.

Results: The doses to the heart, ipsilateral lung and the conformity index were within the recommended values. The homogeneity index was not comparable; however, a section by section qualitative analysis was done and a final plan approved. As per the RTOG toxicity grading system, acute skin reaction grade 3 was observed in 3.6% of treatments to intact breast including nodal regions and in 3.5% of post mastectomy radiation patients.

Conclusion: Single isocenter technique was not feasible as the telecobalt unit did not have multileaf collimators and asymmetric jaws. With improved image based planning, a multi-isocentric technique was planned. By evaluating the dose distribution, beam modifications can be made and treatments can be given with acceptable toxicity.

1. Background

Breast cancer is the leading cancer among females both in the developed and developing countries.[1,2] With recent screening techniques and imaging modalities, many patients are now being diagnosed with early stage breast cancer. The incidence of early breast cancers in the developing countries is rising compared to earlier presentations of locally advanced breast cancer, due to raised awareness among people and also due to various screening programs available in the community. In many countries, due to the limitation in the number of radiotherapy units available, there is a need for availability of low maintenance units like the telecobalt machines, to cater to the radiation needs of such patients.[3] The World Health Organisation (WHO) has recommended the telecobalt machine as a simple effective equipment.[4]

In our center, previously, two dimensional planning was done with the help of X-ray machines and later planning was done using radiotherapy simulator images with skin marks. From 2009, image based conformal therapy in a linear accelerator was the treatment given to all patients. The radiotherapy department treats around 400–500 breast cancer patients a year.

2. Aim

The aim of this study is to treat breast cancer patients, with image based conformal planning using the telecobalt machine with multiple isocenters, in conditions where the linear accelerator was not available due to technical reasons.

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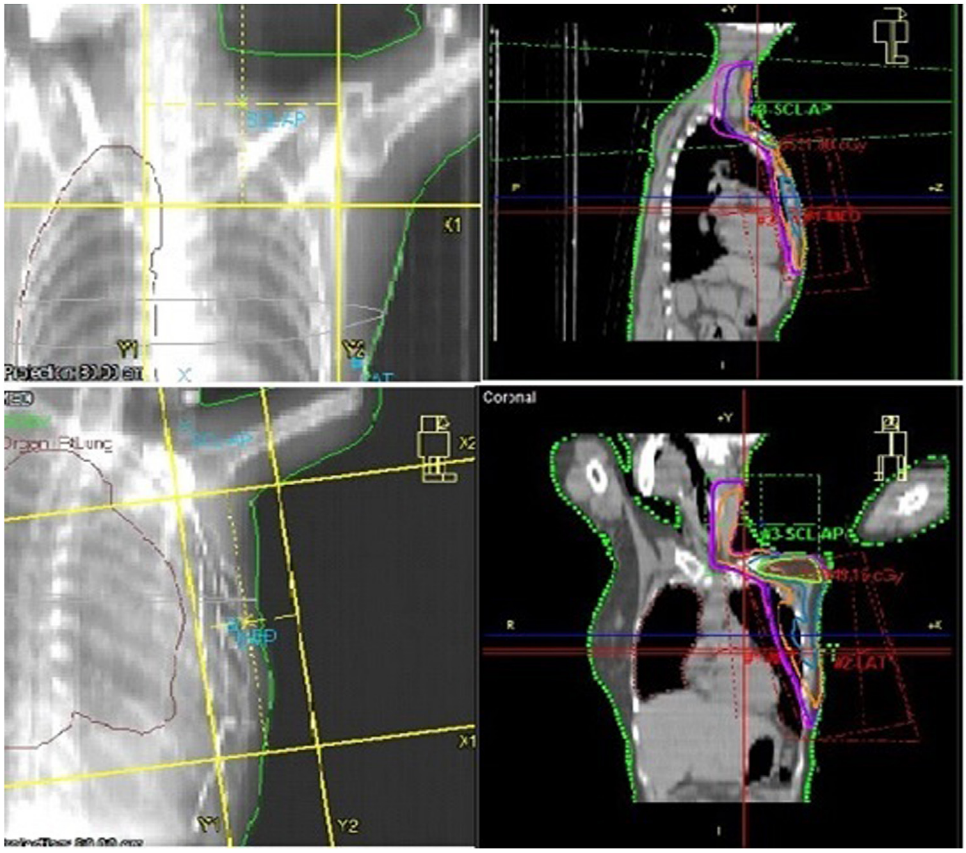

Fig. 1. Tangential fields and supraclavicular fields without collimation and high junction dose.

3. Materials and methods

In this study, 300 breast cancer patients who were planned for treatment in the Theratron Phoenix telecobalt unit were considered. Immobilisation was done using a thermoplastic mould on a breast board. Skin marking was done and radio-opaque markers were placed in the medial, lateral and inferior clinical borders. Planning CT scans with 0.5 cm slice thickness were done with 3 fiducial markers kept on the breast mould at the medial and lateral positions of the breast/chestwall and at the supraclavicular region.

As per Radiation Therapy Oncology Group (RTOG) contouring guidelines,[5] the clinical target volume (CTV) of the breast/chest wall, supraclavicular regions and the internal mammary nodes (IMN) was delineated using the internal mammary vessels as surrogate.[6] Planning target volume (PTV) was generated with suitable margins and the heart, ipsilateral lung and spinal cord were delineated as the organs at risk (OAR). The treatment planning was done using the Oncentra (Version 4.3.0.410, Elekta AB) treatment planning system (TPS).

The treatment planning involved separate plans using the SSD (source to skin distance) technique. Tangential field technique was used to treat the breast/chestwall. A separate plan was done, either a single direct field for the supraclavicular region or two opposing fields when the axilla was included. To get a better understanding on what dose is being delivered to the patient, CT scans were done and treatment planning was carried out on the Oncentra TPS. Dose distributions were calculated with collapsed cone convolution (CCC) algorithm, with a dose grid of 3.0 mm. When three fields were planned, the junction dose was more than 110%, sometimes even as high as 150% of the planned doses in the SSD technique. Also, it was observed that the distribution was not uniform and the volume of the target receiving the maximum dose was higher. Hence, to reduce this and to maintain uniform doses, changes in the planning were attempted.

We evolved the mono-isocentric technique to treat the patients. We had a technical difficulty of not being able to exploit the benefit of half beam block technique to mitigate the lung and heart doses in the case of left sided breast/chestwall treatment, as the available telecobalt machine was not equipped with asymmetric jaws. To minimize the lung and heart doses, we improved our treatment plans by accepting the multi-isocentric planning technique. This technique used the posterior part of the tangential beams, thereby reducing dose to OAR due to beam divergence. After the treatment planning was generated on the three dimensional CT scan sections, we started noticing higher junctional doses. This was due to the technical impossibilities of field border matching between tangential fields and supraclavicular fields (Fig. 1) and due to the beam divergence and overlap. To overcome this problem, we started adjusting the collimator angles and field sizes of both tangential fields as well as the supraclavicular fields with the help of beam's eye view (BEV) tool in the TPS. By using different field sizes and collimator rotation for the tangential and supraclavicular fields, it was possible to reduce the overlap at the junctions, including the high dose received at the junctions (Fig. 2). The distribution of planned dose and the dose volume histogram (DVH) were analysed (Fig. 3).

After approval of suitable plan, the patient was then simulated on the simulator (Nucletron Simulix digital simulator) in the treatment position on a breast board with the thermoplastic mould. The shift from the fiducial marker, as planned, was needed to be implemented and the new isocenters for the fields were marked with their respective planned SSD reading on the mould. The beam parameters, including the field size, gantry and collimator angle,

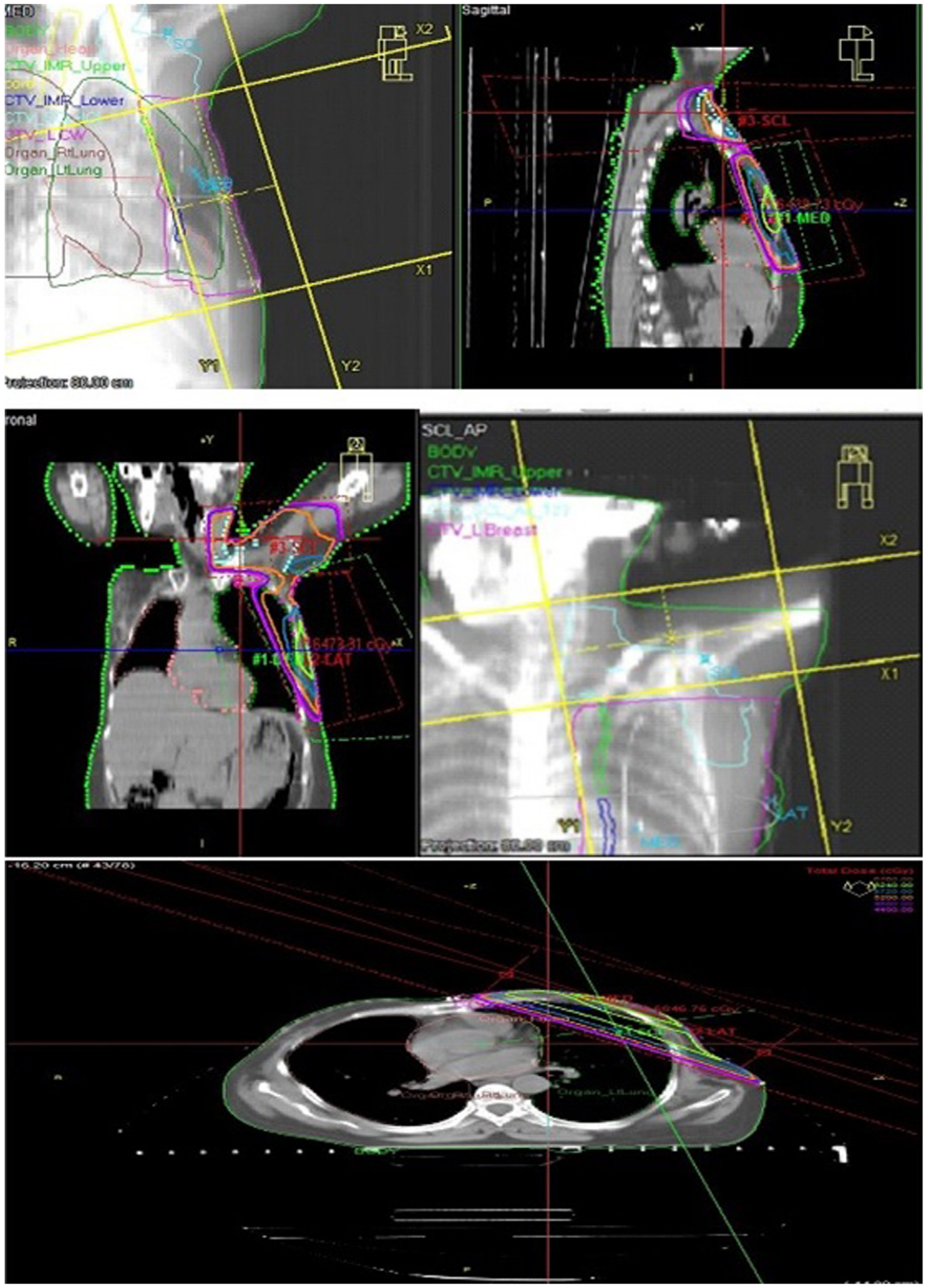

Fig. 2. Tangent and supraclavicular fields with collimation in both to reduce the junction dose.

were applied using the set up generated from the planning system (Fig. 4). The patient was simulated and images were recorded for verification (Fig. 5). This step was very useful for the accurate delivery of cobalt treatment as the therapy unit does not contain an electronic portal imaging device (EPID) for set up verification. The patients were then treated in the telecobalt machine with these fixed parameters. As the build-up dose is at 0.5 cm in cobalt treatments, with careful planning and a no bolus protocol, skin morbidity can be avoided.

A mono-isocentric conformal photon plan with 6 MV X-ray beam for Varian Clinac 2100 linear accelerator was generated for comparison of DVH with the telecobalt treatment plan. Partially wide tangential field technique was employed as the IMN was routinely included in the treatment field. Field in field compensation was used for planning. The treatment planning was carried out with Analytical Anisotropic Algorithm (AAA) on Eclipse TPS.

The total dose to PTV was 46–50 Gy in 23–28 fractions, 180 to 200cGy per day, 5 days a week, delivered over a period of 5–5.5 weeks. The constraints to the OAR, the ipsilateral lung (right or left) and heart were also achieved. For the lung, the volume receiving 20 Gy (V20) was 30% and the Mean Lung dose (MLD) was <15 Gy with a maximum lung distance not more than 3.5 cm maintaining the V20 and MLD constraints. The volume of the heart receiving 25 Gy (V25) was <10%. Due to irregular target contour, the PTV coverage was not adequate with 95% isodose and, hence, 90% isodose was prescribed and found to enclose the target adequately.

The DVH of both treatment plans were analysed for uniformity of dose distribution within the PTV and dose conformity. The homo-

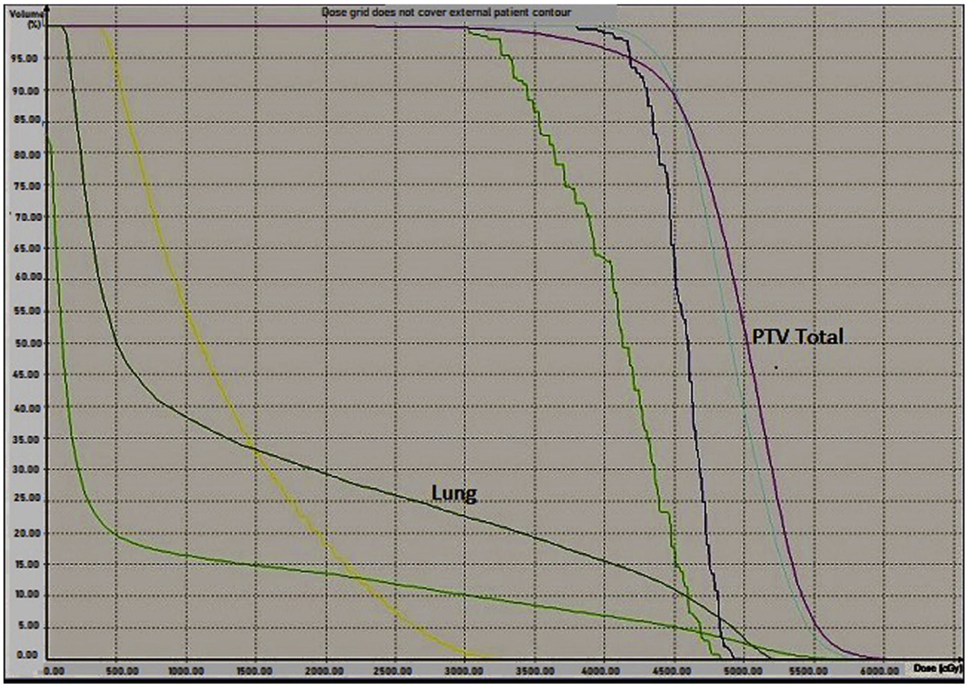

Fig. 3. Dose Volume Histogram.

Table 1
OAR dose comparison between telecobalt and linear accelerator conformal plans.

OAR	Parameter	TelecobaltMean ± SD	Linear acceleratorMean ± SD	p-value
Lung	V20 (%)	26.33 ± 3.72	25.97 ± 3.28	0.268
	MLD (Gy)	13.55 ± 1.74	13.60 ± 1.58	0.837
Heart	V25 (%)	7.03 ± 2.66	6.88 ± 4.10	0.851

SD, Standard deviation.

geneity index (HI) and conformity index (CI) were generated as per the International Commission on Radiation Units and Measurements (ICRU) 83 for both treatment plans.

The HI is defined as the following: (HI of zero is ideal)

$$\mathrm{HI} = \frac{\mathrm{D2\%\text{-}D98\%}}{\mathrm{D50\%}}$$

D2%, D98% and D50% are the dose received by 2%, 98% and 50% of target volume.

The CI is defined as the following: (CI of 1.0 is ideal)

$$\mathrm{CI} = \frac{\text{Volume of PTV covered by reference isodose}}{\text{Volume of PTV}}$$

3.1. Statistical analysis

The parameters of the OAR (Lung V20 and MLD, Heart V25), including the plan maximum dose (Dmax), HI and CI of the telecobalt treatment, were compared with linear accelerator based conformal therapy. DVHs were calculated for each target volume and OAR in all plans for evaluating the coverage of target volume and dose homogeneity. The maximal dose and mean doses were obtained and standard deviations were defined. Chi-square test was used for categorical variables and "t" test was applied for continuous variables to find the difference between the two treatment plans. A p-value of <0.05 was considered as significant.

Table 2
Plan parameter evaluation for telecobalt and linear accelerator conformal plans.

Parameter	Telecobalt Mean ± SD	Linear accelerator Mean ± SD	p-value
Dmax (Gy)	60.93 ± 4.44	49.82 ± 2.79	0.001
HI	0.51 ± 0.07	0.3 ± 0.01	<0.001
CI	1.51 ± 0.17	1.43 ± 0.1	0.05

SD, Standard deviation.

4. Results

Among the 300 breast cancer patients treated, 149 patients were left sided and 151 were right sided. Whenever the nodal areas were included, the upper three internal mammary nodal (IMN) regions were considered for treatment. As with any other conformal treatment, it was difficult to include the IMN regions in the left sided patients. The IMN region was included in 57% of left sided and 70% of the right sided patients.

The doses received by the ipsilateral lung (V20 and MLD) and heart (V25) were comparable between telecobalt and linear accelerator based conformal treatment plans (Table 1). As expected, the plan maximum dose (Dmax) for the telecobalt treatment was higher when compared with the linear accelerator plan. The lack of multileaf collimators and unavailability of field in field technique application with the telecobalt machine resulted in Dmax being higher. The homogeneity index with the linear accelerator based conformal plan was better compared to the telecobalt plan, as expected. The conformity index values were within the recommended values (Table 2). No major acute toxicity was noted in the

Beam	MED	LAT	SCL
DICOM#	1	2	3
Unit	Phoenix MI	Phoenix MI	Phoenix MI
Rad. Type	ISOTOPE	ISOTOPE	ISOTOPE
Algorithm	PB	PB	PB
Nom.Acc.Pot.(MV or MeV)	1.300	1.300	1.300
Uses IEC 61217	No	No	No
SAD (cm)	80.00	80.00	80.00
FY (cm)	**7.00**	**7.00**	**16.00**
Y1	-3.50	-3.50	-8.00
Y2	3.50	3.50	8.00
FX (cm)	**16.00**	**16.00**	**8.00**
X1 (cm)	-8.00	-8.00	-4.00
X2 (cm)	8.00	8.00	4.00
X (cm)	-5.00	9.15	1.00
Y (cm)	-14.00	-14.00	-1.50
Z (cm)	7.56	-1.58	1.29
TPRP (cm)	(2.34, -2.20, 4.21)	(2.34, -2.20, 4.21)	(2.34, -2.20, 4.21)
Table Top Lateral (cm)	5.00	-9.15	-1.00
Table Top Longitudinal (cm)	14.00	14.00	1.50
Table Top Vertical (cm)	-7.56	1.58	-1.29
SSD (cm)	**84.54**	**85.19**	**80.00**
Gantry (degrees)	300.0	125.0	345.0
Gantry Arc Direction	N/A	N/A	N/A
Collimator (degrees)	**15.0**	**345.0**	**3.0**
Couch (degrees)	0.0	0.0	0.0
MLC Type			
Inhomogeneity	2D	2D	2D
Bolus	N/A	N/A	N/A
Wedge ID	N/A	N/A	N/A
Wedge Angle (degrees)	N/A	N/A	N/A
Wedge Orientation	N/A	N/A	N/A
Wedge Type	N/A	N/A	N/A
SWTD (cm)	N/A	N/A	N/A
# of Blocks	N/A	N/A	N/A
Total BLK Tray Factor	N/A	N/A	N/A
Block Tray ID	N/A	N/A	N/A
SBTD (cm)	N/A	N/A	N/A
Applicator Label	N/A	N/A	N/A
Applicator ID	N/A	N/A	N/A
Applicator Type	N/A	N/A	N/A
Number of Fractions	23	23	23
MU or min / Fraction	**2.560**	**2.623**	**3.415**
Dose Spec. Point	N/A	N/A	N/A

100% PRESCRBED FOR 200cGy/23#
MEDIAL TANGENT (MED) – Isocenter is at 2cm inferior to the lead marker level, SSD 82cm at Gantry 0
LATERAL TANGENT (LAT) – Isocenter is 2cm inferior to the lead marker level, SSD 83cm at Gentry 0
SUPRACLAVICULAR (SCL) – Isocenter is 1.5cm inferior and 1cm towards patients left side, SSD 80cm at Gantry 0

Fig. 4. Set up sheet for field shift.

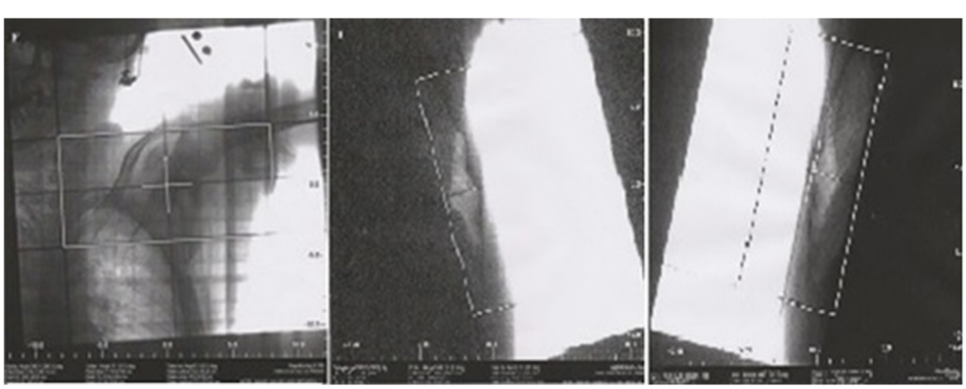

Fig. 5. Verification with nucletron simulation applying field shift.

treated patients. Acute skin toxicity was graded using the RTOG grading system.[7] Grade 3 skin reaction was noted in 3.6% of those who received treatment to the intact breast, including the nodal regions, and in 3.5% of post mastectomy patients. However, with image guidance and planning as described above, it was possible to reduce the Dmax and achieve reasonably acceptable HI and CI. A qualitative analysis of the telecobalt treatment plan was done by evaluating the CT images planned, section by section, in addition to analysis of high and low doses. The HI and CI were used only as a supplement and not as a sole predictor of plan quality.

5. Discussion

The main concern when treating with cobalt therapy was the beam characteristics.[8,9] The large penumbra at the edge of the beam was of concern especially when treating the breast or chest-wall with nodal areas. Several investigators have cited the benefit of using MLC in telecobalt unit[10–14] so that the treatments can be in par with treatments using a linear accelerator with MLC. The ease of set-up, affordability and low maintenance have caused telecobalt units to be equipment of choice in delivering radiotherapy treatments in low income countries where no radiotherapy units are available for treatment delivery.[15] This motivated us to plan three dimensional treatment planning with image guidance and set up verification on a simulator with the available telecobalt unit at the department. Our telecobalt unit did not have MLC and the treatment planning was done with the aim to deliver uniform doses to PTV with acceptable doses to OAR. With planning systems available today, it is possible to generate conformal doses to the planned target volumes with reduced junction dose, maximum dose and doses to OAR. When large fields were used, an extended SSD technique was used.

6. Conclusion

From early days, the treatment of carcinoma breast is a challenging task due to geometric location and adjacent organs at risk. Two opposing tangential fields and later advancements in treatment planning system with conformal therapy, intensity modulated radiotherapy (IMRT), volumetric arc therapy (VMAT) were employed. However, the time has not yet come to say good bye to cobalt beam therapy. Many centers in low income countries are still using telecobalt machines to deliver treatments. An attempt towards conformal and image based treatment with careful planning and beam modifications including set up verification on the simulator was tried and executed. No major treatment related morbidities were observed. The skin toxicity observed was also well within the acceptable limits.

Conflict of interest

None.

Financial disclosure

None declared.

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